

PROCEEDINGS
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THE VALIDITY OF *CANDACIA TUBERCULATA*
WOLFENDEN AND COMPARISON WITH
C. BRADYI SCOTT
(COPEPODA, CALANOIDA)

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As part of a study of the copepod family Candaciidae in the surface waters of the Indian Ocean, specimens have been examined from over 300 zooplankton collecting stations of the International Indian Ocean Expedition. A species of *Candacia*, closely resembling *C. bradyi* Scott, 1902, was found at 16 stations and another species referable to *C. bradyi* was found at 9 stations. As a result of closer examination it was concluded that the former species is actually *C. tuberculata* Wolfenden, 1905, a species hitherto considered a junior synonym of *C. bradyi*. The morphological features which distinguish the two species are discussed below.

Candacia tuberculata Wolfenden, 1905

Figures 1-10, Plate I a,b; Plate II c,d; Plate III a,b

- C. tuberculata* Wolfenden, 1905:1013, plate 96, figures 40-44 (♂). NEW SYNONYMY.
- C. catula* var. *similis* Wolfenden, 1905:1012-1013 (♀). NEW SYNONYMY.
- C. bradyi* Scott, 1909:156, plate 47, figures 1-9 (♂).—Pesta, 1912:49, figures 9a-d (♀, ♂).—Sewell, 1912:366, plate 23, figures 6,7 (♀).—Sewell, 1914:229.—Tanaka, 1935:210-227, plate 4, figures 5-17 (♀, ♂).—Mori, 1937:80, plate 53, figures 8-12 (♀).—Grice, 1963:174, figures 9, 47 (♀, ♂).—Tanaka, 1964:244. NEW SYNONYMY.
- C. curva* Mori, 1932:171, 175, plate 53, figures 8-12 (♀). NEW SYNONYMY.

The first segment of the female urosome (Figs. 1-4) is slightly asymmetrical. A slender spine projects posteriorly from the ventral surface of the second segment (Fig. 5), and there are two small bulblike

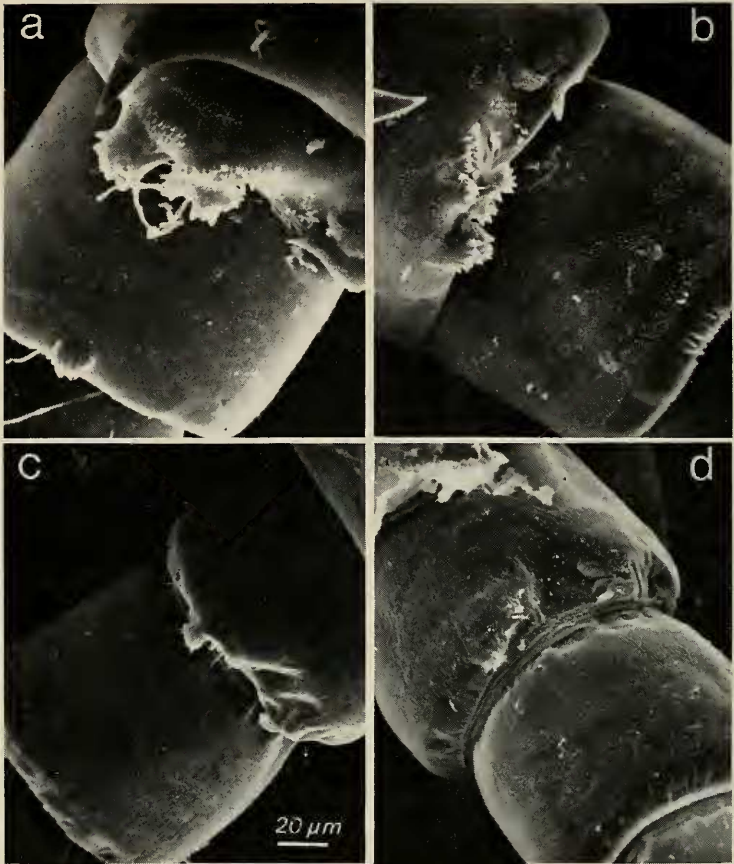
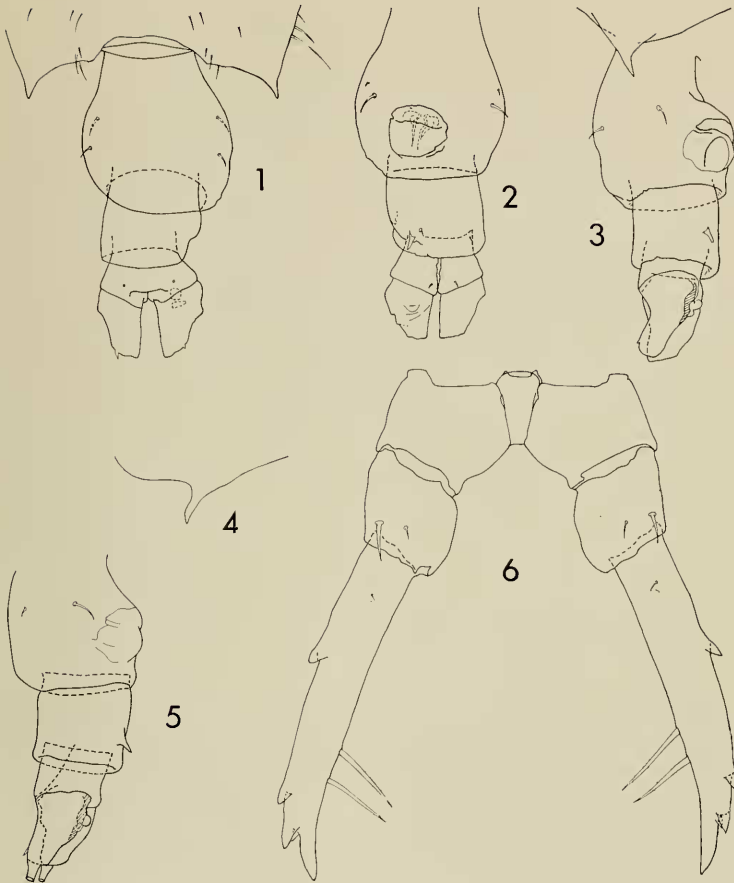


PLATE I. Scanning micrographs of the right side of the male urosome segments 1 and 2 of *Candacia tuberculata* (above) and *C. bradyi* (below). Specimens from the following locations: a. CONCH cr. 198, sta. 55 (1°19'N, 75°37'E); b. DANA sta. 3685 (4°22'N, 121°16'E); c,d. Pola-Rotes Meer Expedit. sta. 150 (12°34'N, 43°36.6'E).

processes on the ventral surface of the right furca, beneath which the cuticle is thickened. The distal third of the left fifth foot is pigmented. Spines on the left foot (Fig. 6) are also pigmented and rounded.

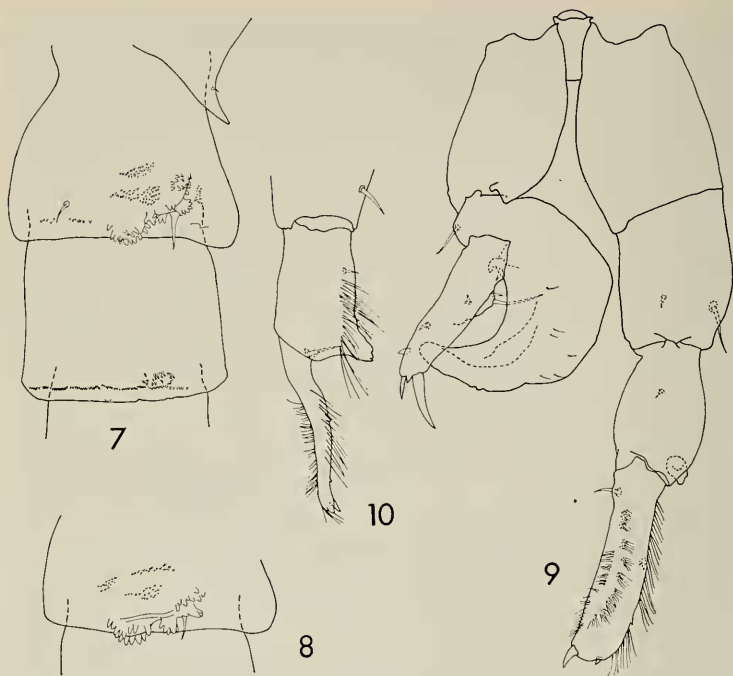
The first segment of the male urosome bears an outgrowth on the right side (Figs. 7, 8; Plate I:a,b) consisting of a conspicuous dorsal lobe and two smaller ventral lobes and is ornamented with short, pointed protuberances. There is a smaller outgrowth on the right side of the



FIGS. 1-6. *Candacia tuberculata* Wolfenden. Female. 1-3, urosome, dorsal, ventral, right side respectively; 4-5, ventral spine on urosome segment 2; 6, fifth feet, posterior. Figs. 1-2 from CONCH cr. 198, sta. 55 ($10^{\circ}19'N$, $75^{\circ}37'E$); Figs. 3-6 from VARUNA 2041 ($15^{\circ}00'N$, $73^{\circ}28'E$).

second urosome segment (Fig. 7; Plate II:c,d) which is also ornamented with short, pointed protuberances. The fourth segment of the left fifth foot is longer than the third segment (Figs. 9, 10). The flattened tooth-like process on the third segment bears terminally a hooklike blunt point and subapically two broadly rounded points (Fig. 10; Plate III:a,b).

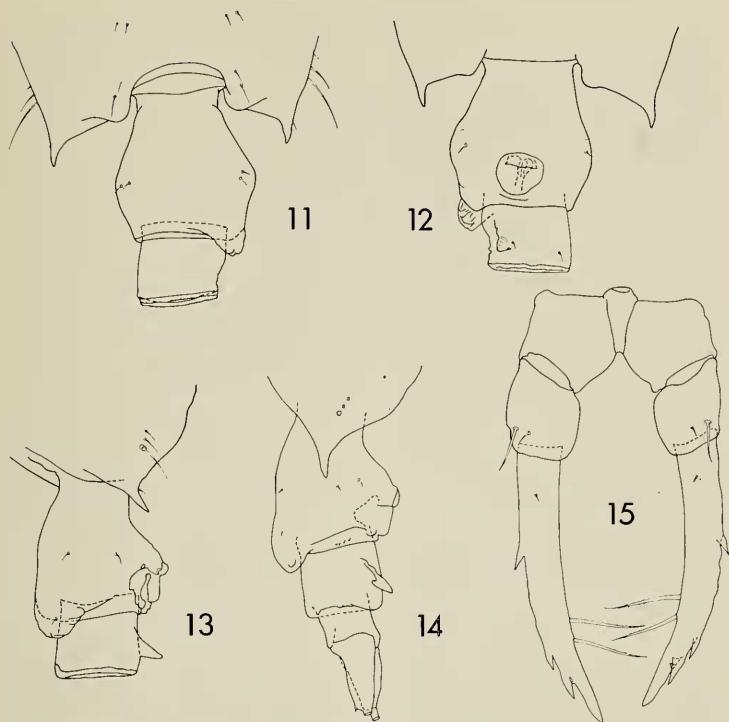
C. tuberculata was identified from 16 stations located in neritic waters of the northern and eastern Arabian Sea, the Strait of Malacca and from



FIGS. 7-10. *Candacia tuberculata* Wolfenden. Male. 7, urosome segments 1 and 2, right side; 8, urosome segment 1, right side (another specimen); 9, fifth feet, anterior; 10, left fifth foot, segments 3 and 4, left side. Figs. 7-10 from VARUNA 2041 (15°00'N, 73°28'E).

one station near the southern coast of Java. The author was able to examine 22 vials of specimens collected from the Red Sea, Persian Gulf and Indonesian waters and identified by Pesta (1912, 1941) as *C. bradyi*. Another vial from Pesta's collection contained 2 females and 1 male collected in Indonesian waters and identified as *C. tuberculata*. All Pesta's specimens are referable to *C. tuberculata* except those collected in the Red Sea. The species was also found at Dana Stas. 3685 and 3696 in the Celebes and Sulu Seas, respectively. Specimens identified as *C. bradyi* (Tanaka, 1964) from Japanese waters were also made available to the author and are referable to *C. tuberculata*.

A female specimen from CONCH cruise 198, sta. 55 (10°19'N, 75°37'E, 0-200 m depth of collection, 10 Oct. 1963) has been designated a neotype and deposited in the National Museum of Natural History, Smithsonian Institution (USNM 143824). Specimens of both sexes from this same collection have been designated plesiotypes and deposited in the National



FIGS. 11–15. *Candacia bradyi* Scott. Female. 11–13, urosome segments I and 2—dorsal, ventral, right side respectively; 14 urosome, right side; 15, fifth feet, posterior. Figs. 11–13 from METEOR cr. 1, sta. 95 (11°42'N, 48°49'E); Figs. 14–15 from ATLANTIS II, cr. 15, sta. 545 (11°52'N, 46°52'E).

Museum of Natural History (USNM 143825), the Indian Ocean Biological Centre, Cochin, India and the Woods Hole Oceanographic Institution.

Candacia bradyi Scott, 1902

Figures 11–20; Plate I c,d; Plate II a,b; Plate III c,d

C. bradyi Scott, 1902:406, plate 1 figures 9–12 (♂).—Pesta, 1941:163, figure 3 (♀, ♂). NEW SYNONYMY.

non-*C. bradyi* Carl, 1907:9–17, plate 1, figures 8–14 (partim?) (= *C. discaudata*). NEW SYNONYMY.

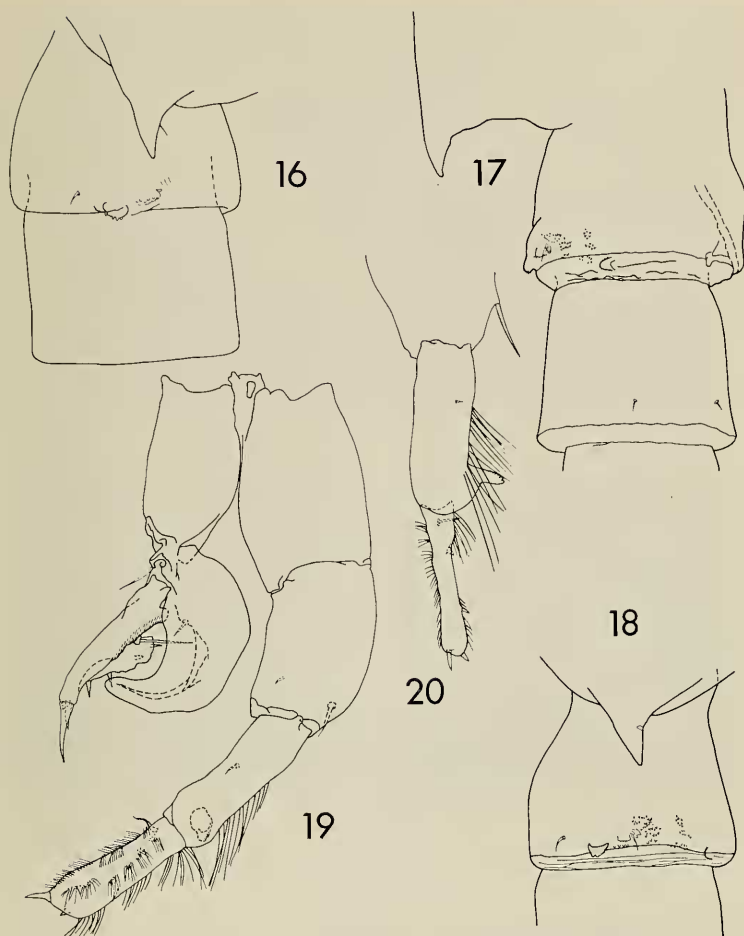
The first segment of the female urosome (Figs. 11–14) bears a prominent dorsal lobe which is displaced somewhat to the right side and extends posteriad. The second segment bears a stout ventral spine



PLATE II. Details of ornamentation on the urosome of *C. bradyi* segment 1 (above); *C. tuberculata*, segment 2 (below). Figs. a, b, c, d from the same specimens as Plate I Figs. c, d, a, b respectively.

projecting posteriorly. Both fifth feet bear sharp, pointed external spines (Fig. 15). There is a small outgrowth on the right side of the first segment of the male (Figs. 16–18; Plate I:c,d; Plate II:a,b) which is often indistinctly lobate. The fourth segment of the left fifth foot (Figs. 19, 20) is shorter than the third segment. An elongate toothlike process on the third segment (Fig. 20; Plate III:c,d) terminates in about 10 small rounded truncated nodules arranged in several rows.

C. bradyi was found at 9 stations: 3 in the Red Sea, 2 in the Gulf of Aden, and 4 in the western Arabian Sea; its occurrence at 11 stations in the Red Sea (Pesta, 1941) has been confirmed.



FIGS. 16–20. *Candacia bradyi* Scott. Male. 16, urosome segments 1 and 2, right side; 17, urosome segments 1 and 2, ventral and slightly from the right side; 18, urosome segment 1, right side; 19, fifth feet, anterior; 20, left fifth foot, segments 3 and 4, left side. Figs. 16, 20 from ATLANTIS II, cr. 15, sta. 545 (11°52'N, 46°52'E); Figs. 17–19 from METEOR cr. 1, sta. 93A (12°43'N, 48°31'E).

A female specimen from Anton Bruun cruise 9, station 473 (17°05'N, 40°53'E, 0–50 m depth of collection, 12 July 1965) has been designated a neotype and deposited in the National Museum of Natural History (USNM 143826). Specimens of both sexes from this same collection have

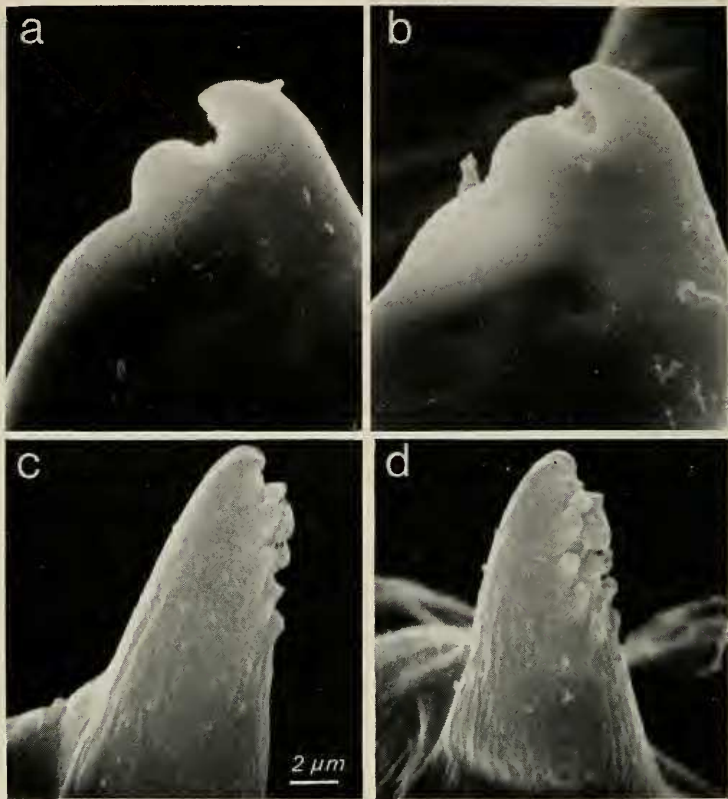


PLATE III. Toothlike process on the fourth segment of the fifth foot from the same specimens as in Plate I Figs. a, b, c, d respectively.

been designated plesiotypes and deposited in the National Museum of Natural History (USNM 143827). Plesiotypes of both sexes have been deposited at the Indian Ocean Biological Centre, Cochin, India and at Woods Hole Oceanographic Institution.

Remarks: At the time of the original description of *C. tuberculata*, Wolfenden (1905) mentioned that this species may actually be *C. bradyi*, a species which at that time was known only from male specimens collected in the Gulf of Aden. Scott (1909) synonymized *C. tuberculata* with *C. bradyi* and provided a new description of *C. bradyi* based on specimens collected in waters of the East Indies, far removed from the type-locality. Scott's description was based on male specimens of *C. tuberculata*. The author has been unable to locate the type material upon which Scott's original and subsequent descriptions were based, nor

TABLE 1. Size comparisons of *Candacia tuberculata* with *C. bradyi*. The Mann-Whitney U test, corrected for ties, indicated a significant difference ($P < .01$) between the species for all measurements. Measurements in mm.

		<i>C. tuberculata</i>	<i>C. bradyi</i>
Female:			
Cephalothorax	n	36	29
	mean	1.40	1.25
	range	1.28-1.60	1.06-1.70
	std. dev.	.069	.123
Total length	n	21	18
	mean	1.71	1.59
	range	1.56-1.98	1.40-2.10
	std. dev.	.094	.179
Male:			
Cephalothorax	n	38	30
	mean	1.29	1.19
	range	1.16-1.42	1.08-1.46
	std. dev.	.061	.092
Total length	n	22	22
	mean	1.71	1.53
	range	1.60-1.88	1.44-1.78
	std. dev.	.068	.086

Wolfenden's type material although inquiries were made at the British Museum; Royal Scottish Museum, Edinburgh; Marine Laboratory, Aberdeen; Biology Dept., Liverpool Univ.; and at the Leiden Museum.

Both species are very similar in external morphology and, although *C. tuberculata* is significantly larger than *C. bradyi* ($P < .01$), there is considerable overlap in cephalothorax and total lengths (Table 1). In the female the most obvious differences are found in the urosome. The conspicuous dorsolateral lobe on the first segment of the urosome of *C. bradyi* is not present on the urosome of *C. tuberculata*; the ventral spine on the second segment is more slender in *C. tuberculata* and *C. bradyi* lacks the bulblike processes found on the right furca of *C. tuberculata*.

The female fifth feet have a similar pattern of spines and setae in both species. However, in *C. tuberculata* the distal third of the left foot is pigmented. The spines on the left foot are also pigmented and rounded. The fifth feet of *C. bradyi* lack pigmentation and the spines on both feet are pointed.

In the male, the outgrowth on the right side of the first segment of the urosome is considerably more prominent in *C. tuberculata*. The outgrowth

on the second segment of *C. tuberculata* is absent from *C. bradyi*. No obvious differences were observed in the geniculate antennae of the two species.

Wolfenden (1905) noted what appeared to be a difference in the last segment of the male left fifth foot between *C. tuberculata* and *C. bradyi*. In my specimens, the ratio of the length of the last segment to the third segment is greater than one in *C. tuberculata* and less than one in *C. bradyi*. The toothlike process on the third segment is more blunt in *C. tuberculata* and produced distally into a few distinct blunt points (Wolfenden, 1905; Scott, 1909). In *C. bradyi*, the toothlike process terminates in a single, blunt point and bears a cluster of rounded truncated nodules on one side.

Wolfenden did not consider the possibility that *C. catula* var. *similis* represented the unknown female of his species although both came from the same area and he stated that *C. tuberculata* "has most affinity with *C. catula*." I have examined 20 female specimens of *C. catula* from collections obtained near the type-locality of *C. catula* var. *similis* (ΑΝΤΩΝ ΒΡΥΝ Stations 106 (17°27'N, 70°27'E), 111 (8°09'N, 70°02'E), 114 (01°30'N, 70°01'E). The mean length of these females was only 1.39 mm \pm .046 std. dev. and the maximum length was 1.50 mm. In agreement with *C. catula* sensu strictu, all of these specimens had 3 setae on the inner margins of the fifth pair of feet with one exception, a specimen which had 3 setae on the left fifth foot and 2 setae on the right. Wolfenden reported measurements for *C. catula* var. *similis* that are in the upper range for *C. tuberculata* (approx. 2.00 mm). He also described the fifth feet as bearing 2 setae which is also in agreement with *C. tuberculata*. Even though no figures were provided, there is little doubt that Wolfenden's *C. catula* var. *similis* is referable to *C. tuberculata*.

The known distribution of *C. tuberculata* is the northern and equatorial Indian Ocean and warm waters of the eastern Pacific Ocean. The distribution of *C. bradyi* appears to be limited to the Red Sea and eastern Arabian Sea.

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